Bulletin of the Geological Survey of Japan, vol. 44(11), p. 685–691, 1993

Preliminary report on geochemistry of Lower Cretaceous Dsunbayan oil shales, eastern Mongolia

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YAMAMOTO, Masanobu, BAT–ERDENE, Delegiin, ULZIIKHISHIG, Pureyiin, ENOMOTO, Minoru, KAJIWARA Yoshiteru, TAKEDA Nobuyori, SUZUKI Yuichiro, WATANABE Yoshio and NAKAJIMA Terumasa (1993) Preliminary report on geochemistry of Lower Cretaceous Dsunbayan oil shales, eastern Mongolia. *Bull. Geol. Surv. Japan*, vol. 44(11), p. 685–691, 4fig., 2tab.

Abstract: The organic carbon and sulfur contents, oil yield, and kerogen types were determined for twenty-six oil shales from the Dsunbayan Group, Lower Cretaceous lacustrine sedimentary sequences in eastern Mongolia by the combustion, Fischer-Assay and Rock-Eval methods. The Dsunbayan oil shales show large variations of organic carbon content (1.7–21.3 wt.%) and oil yield (0.3–11.8 wt.%). The oil yields of Eidemt samples are higher than those of Bayan-Erkhit and Shawart-ovoo samples, and most of those exceed the lowest limit for oil shales (10 US gallon per short ton; 4.7 wt.%), although it does not necessarily mean that those shales are "economical" due to the recent relatively low market price of crude oil. Rock-Eval analysis shows high hydrogen index and relatively high Tmax values for most samples, which means that Type I kerogen (typical oil shale type) dominates in these samples. The high organic carbon contents, oil yields and hydrogen indices of Dsunbayan oil shale samples also indicate that these oil shales are "excellent" potential petroleum source rocks, which probably generated oils for some oil seepages and bitumen deposits found in the Choir Nyalga and Central Gobi basins.

1. Introduction

The oil shale is defined to be any shallow rock yielding oil in commercial amount on pyrolysis (Tissot and Welte, 1984). The value of 10 US gallon per short ton (about 4.7 wt.%) is frequently used as the lowest limit of oil yield for oil shale. The world proven reserve of oil shale is about three trillion barrels, which is several times as that of crude oil (World Energy Conference, 1980). Since the first construction of an industrial plant in Autun, France in 1883, the oil shale industry had been developed in many countries. However the decline of market price of crude oil after World War II has made the oil shale industry "uneconomical." Accordingly, almost all

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plants have been closed with some exceptions (e.g., that of Fushun, China). Despite such recent economic situation, the oil shale still has an importance as the potential energy source and raw material substitute for crude oil, and has even an economic importance in the countries and areas isolated geographically or politically.

The Lower Cretaceous Dsunbayan Group is distributed in the eastern Mongolian Mesozoic basins and is composed of lacustrine sedimentary sequences with thick oil shale horizons and coal measures (Bat-Erdene and Enkhtugs, 1987). While the coal is used as a main energy source in eastern Mongolia, the oil shale still remains unused. The geological and geochemical surveys on those oil shales had been conducted by some Mongolian and Estonian institutes; however the results have not yet been published. At present, little published data is available about the geochemical aspects of the Dsunbayan oil shales. The survey and evaluation of the Dsunbayan oil shale remain a future subject in the exploration activity for fuel resources in Mongolia.

The Dsunbayan oil shale is undoubtedly a petroleum source rock of the Dsunbayan oil field (1941–1969) in the East-Gobi basin (e.g., Petzet, 1990). The Dsunbayan Group is correlated to the Lower Cretaceous lacustrine source rocks distributed in Chinese territory (e.g., Songliao, Erlian, North China, Subei, Ordos, Jiuquan, Tarim and Junggar basins) with some giant oil fields. The source rock evaluation for the Dsunbayan oil shale is a future indispensable process for the oil exploration and reserve estimation in the eastern Mongolia area.

This paper reports the preliminary results of organic elemental analysis, Fissher-Assay analysis and Rock-Eval pyrolysis for twenty-six oil shales from the Bayan-Erkhit, Eidemt and Shawart-ovoo areas. This report is one of the first-year results of Institute for Transfer of Industrial Technology (ITIT) Project "Research on exploration and development of mineral resources in Mongolia" being conducted by Institute of Geology and Mineral Resources, Mongolia and Geological Survey of Japan. The oil shale and coal samples provided for this study were taken by some of the authors (M.Y., D.B. and P.U.) during the field survey in August 1991.

2. Geology

The East Mongolian coal and oil shale province covers six Mesozoic basins (Choir-Nyalga, Central Gobi, East Gobi, Choibalsan, Sukhe-Bator and Tamsag basins) bearing coal and oil shale in eastern Mongolia (Fig. 1; Bat-Erdene and Enkhtugs, 1987). The basins are developed in the accretional terrain on the southern margin of the Siberian craton, and are formed by rift and graben deformations initiated in late Jurassic time (Petzet, 1990). After the rift filling with conglomerates, brrecia and volcanics during late Jurassic time, continental deposits with lacustrine clastics (Dsunbayan Group) continued as the rift fill sequence during early Cretaceous time (Fig. 2; Petzet, 1990). Based on the similarity of the timing and mechanisms of basin developments, the East Mongolian Province can be regarded as the northern extension of the East China Petroleum Province defined by Zhai *et al.* (1988).

The Dsunbayan Group is 1800 meters in the maximum thickness and is subdivided into the Shinekhudag oil shale-bearing Formation, the Khukhteg coal-bearing Formation and the Barunbayan sandy conglomerate Formation from the bottom up (Fig. 2; Bat-Erdene, 1992). The Shinekhudag oil shale-bearing Formation unconformably overlies the underlying formations. The lower part of the formation is composed of 100 meter-thick sandy conglomerates, while the upper part is composed mainly of mudstone with subordinate sandstone, limestone, siderite, dolomite, marl and siltstone. The Khuhteg coal-bearing Formation is composed of conglomerate, sandstone, siltstone, coaly shale with thick coal measures. This formation varies largely in thickness, and is from 730 to 770 meters in the maximum thickness in the Choibalsan and Tamsag basins. The Barunbayan sandy conglomerate Formation is composed mainly of sandstone with conglomerate, fine-grained sediments and tuffaceous sediments. Basic to intermediate volcanics are found in the lower part of this formation in the Nyalga and Choibalsan basins. This formation varies in thickness from 30 to 250 meters.

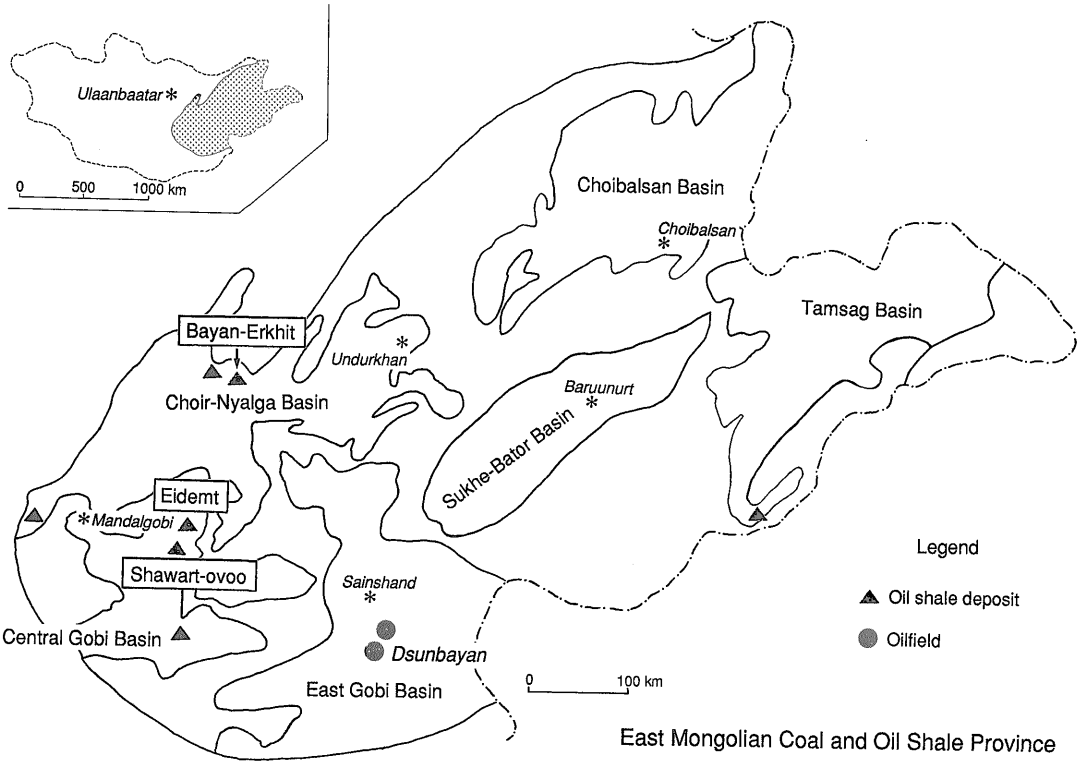

Fig. 1 Map showing the distribution of Mesozoic basins and sampling locations in the East Mongolia coal and oil shale province. Modified from Bat-Erdene and Enkhtugs (1987).

3. Samples and analytical methods

Twenty-six oil shales from the Shinekhudag Formation (four samples from the Bayan-Erkhit area, ten from the Eidemt area and twelve from the Shawart-ovoo area) were provided for this study. The sampling location and the rock types are shown in Fig. 1 and Table 1, respectively.

Determination of organic carbon content was carried out using Kokusai Denki VK–111 carbon and sulfur analyzer after removing carbonate minerals with 3N HCl. Determination of total sulfur was carried out using Horiba EMIA–520 carbon and sulfur analyzer. Determination of oil yield was carried out by the Fischer-Assay method (Ryomei Giken MRF–81W analyzer). The temperature programmed from room temperature to 500℃ at 10℃/min., with a final hold time of 20 min., according to the method of USBM no. 5239. Rock–Eval analysis was carried out using IFP Rock–Eval II.

4. Results and discussion

The organic carbon content of oil shales shows a wide variation (Table 2). Most of Eidemt samples have higher organic carbon contents than Bayan–Erkhit and Shawart-ovoo samples, and have much higher values than Lower Cretaceous lacustrine source rocks of the Songliao basin, China (1.5–8.4 wt.%; Yang *et al.*, 1985).

The oil yields also show a wide variation (Table 2). Eidemt samples show higher oil yield than Bayan-Erkhit and Shawart-ovoo samples. As is shown in Fig. 3, the oil yields of Eidemt samples are lower than those of Green River oil shales, Coloradó, USA and in almost same range as those of Autun shales, France, while those of Bayan-Erkhit and Shawart-ovoo samples are lower than those of Autun shales, and are higher than that of Fushun shale, China. Most of the oil yields of Eidemt samples (seven samples among

System	Period	Stage	Stratigraphic unit	
Cretaceous	Early	Albian Aptian Barremian Hauterivian	Dsunbayan Group	Barunbayan Formation
				Khukhteg Formation
				Shinekhudag Formation
		Valanginian Berriasian Tithonian	Tsagaantsav Group	
Jurassic	Late	Tithonian Kimmeridgian	Sharilin Group	
	Early-Middle	Bathonian Lias	Khamarkhoovor Group	

Fig. 2 Generalized stratigraphic column in eastern Mongolian Mesozoic basins. Modified from Petzet (1990) and Bat-Erdene (1992).

nine) exceed the lowest limit for oil shales (10 US gallon per short ton; 4.7 wt.%), although it does not necessarily mean that those are "economical," considered from the view of the recent relatively low market price of crude oil.

Most Mongolian samples show conversion ratios in almost same ranges (ca. 35–60%; Table 2). Those ranges are classified as the common group of the world oil shales (Tissot *et al.*, 1984).

H. I–O. I diagrams (Fig. 4) show that most samples are plotted in the region of immature Type I and/or II kerogens. Also, those samples except two samples (Eidemt nos. 3 and 4) show almost identical and high Tmax values (440–452℃), despite of their low maturity expected from their H.I. values. Since the combination of high H.I. values and the identical and high Tmax

Table 1 List of oil shale samples from the Dsunbayan Group

Sample name	Rock type	Formation name	Age
	Bayan-Erkhit		
no.5	dark brownish gray laminated mudstone	Shinekhudag	Early Cretaceous
no.7	dark brownish gray laminated mudstone	Shinekhudag	Early Cretaceous
no.8	dark brownish gray laminated mudstone	Shinekhudag	Early Cretaceous
no.9	dark brownish gray laminated mudstone	Shinekhudag	Early Cretaceous
	Eidemt		
no.1	dark brouwnish gray laminated mudstone	Shinekhudag	Early Cretaceous
no.2	dark brouwnish gray laminated mudstone	Shinekhudag	Early Cretaceous
no.3	dark brouwnish gray laminated mudstone	Shinekhudag	Early Cretaceous
no.4	dark brouwnish gray laminated mudstone	Shinekhudag	Early Cretaceous
no.5	beige gray laminated mudstone	Shinekhudag	Early Cretaceous
no.6	dark brouwnish gray laminated mudstone	Shinekhudag	Early Cretaceous
no.7	dark brouwnish gray laminated mudstone	Shinekhudag	Early Cretaceous
no.8	dark brouwnish gray laminated mudstone	Shinekhudag	Early Cretaceous
no.9	dark brouwnish gray laminated mudstone	Shinekhudag	Early Cretaceous
no.10	dark brouwnish gray laminated mudstone	Shinekhudag	Early Cretaceous
	Shawart-ovoo		
no.1	bluish gray laminated calcareous mudstone	Shinekhudag	Early Cretaceous
no.2	bluish gray laminated calcareous mudstone	Shinekhudag	Early Cretaceous
no.3	bluish gray laminated calcareous mudstone	Shinekhudag	Early Cretaceous
no.4	bluish gray laminated calcareous mudstone	Shinekhudag	Early Cretaceous
no.5	bluish gray laminated calcareous mudstone	Shinekhudag	Early Cretaceous
no.6	bluish gray laminated calcareous mudstone	Shinekhudag	Early Cretaceous
no.7	bluish gray laminated calcareous mudstone	Shinekhudag	Early Cretaceous
no.8	bluish gray laminated calcareous mudstone	Shinekhudag	Early Cretaceous
no.9	bluish gray laminated calcareous mudstone	Shinekhudag	Early Cretaceous
no.10	bluish gray laminated calcareous mudstone	Shinekhudag	Early Cretaceous
no.11	bluish gray laminated calcareous siltstone	Shinekhudag	Early Cretaceous
no.12	bluish gray bioturbated calcareous siltstone	Shinekhudag	Early Cretaceous

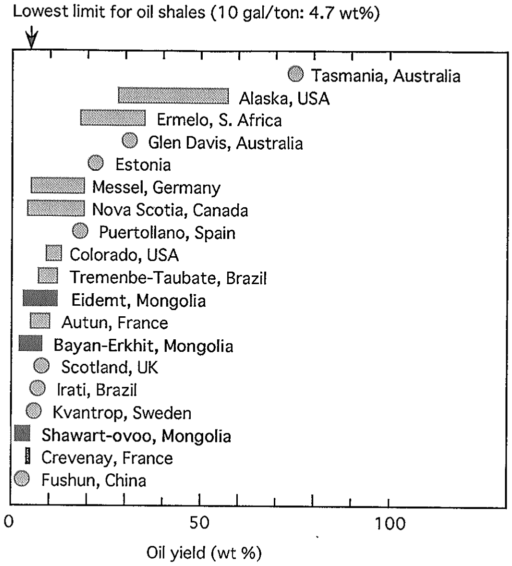

Fig. 3 Oil yields of the world oil shales. Data from Tissot and Welte (1984) and this study.

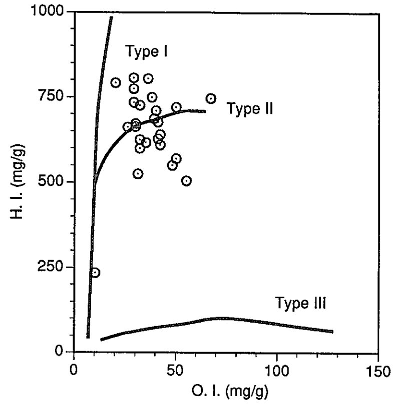

Fig. 4 H.I.–O.I. diagrams for oil shale samples from the Bayan-Erkhit , Eidemt and Shawart-ovoo areas

Table 2 Contents of organic carbon, total sulfur and shale oil (oil yield) and Rock-Eval data for Lower Createceous Dsunbayan oil shales from the Bayan-Erkhit, Eidemt and Shawart-ovoo deposits, eastern Mongolia.

Sample name	TOC wt%	TS wt%	C/S	Oil yield wt%	Conver. R. %	Tmax deg	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	H.I (mg/g)	O.I (mg/g)	P.I	S1+S2 (mg/g)	S2/S3
						Bayan-Erkhit								
no.5	9.90	0.22	45	5.29	45	451	1.60	65.50	2.60	662	26	0.02	67.10	25.19
no.7	8.29	0.26	32	7.70	79	452	1.23	49.73	2.65	600	32	0.02	50.96	18.77
no.8	3.80	0.13	29	2.03	45	449	0.57	19.23	2.09	506	55	0.03	19.80	9.20
no.9	6.20	0.51	12	3.60	49	448	0.71	35.35	3.12	570	50	0.02	36.06	11.33
						Eidemt								
no.1	13.03	0.35	37	8.57	56	446	1.21	95.79	3.73	735	29	0.01	97.00	25.68
no.2	10.82	0.23	47	6.20	49	449	1.96	67.94	4.44	628	41	0.03	69.90	15.30
no.3	15.60	0.27	58	10.82	59	422	10.19	113.23	5.00	726	32	0.08	123.42	22.65
no.4	21.31	0.35	61	11.16	45	429	10.52	159.82	8.07	750	38	0.06	170.34	19.80
no.5	5.83	0.17	34	2.89	42	450	0.42	38.72	1.77	664	30	0.01	39.14	21.88
no.6	14.60	0.24	61	9.07	53	445	2.81	103.59	5.82	710	40	0.03	106.40	17.80
no.7	17.50	0.30	58	n.d.	n.d.	445	4.41	135.58	5.00	775	29	0.03	139.99	27.12
no.8	7.97	0.15	53	4.03	43	446	1.35	48.64	3.38	610	42	0.03	49.99	14.39
no.9	13.07	0.24	54	6.42	42	444	3.86	87.83	3.86	672	30	0.04	91.69	22.75
no.10	17.37	0.55	32	11.82	58	442	7.52	139.80	6.23	805	36	0.05	147.32	22.44
						Shawart-ovoo								
no.1	7.36	0.33	22	4.10	47	440	2.21	49.82	3.00	677	41	0.04	52.03	16.61
no.2	8.62	0.20	43	5.22	51	440	6.52	53.89	2.79	625	32	0.10	60.41	19.32
no.3	7.33	0.80	9	4.56	53	445	2.13	38.46	2.30	525	31	0.05	40.59	16.72
no.4	4.03	0.20	20	2.04	43	447	0.50	30.10	2.70	747	67	0.02	30.60	11.15
no.5	3.33	0.21	16	1.42	36	448	0.43	26.37	0.68	792	20	0.02	26.80	38.78
no.6	7.71	0.25	31	4.74	52	446	1.33	62.23	2.23	807	29	0.02	63.56	27.91
no.7	9.61	0.40	24	n.d.	n.d.	443	2.77	69.25	4.81	721	50	0.04	72.02	14.40
no.8	4.59	0.10	46	2.89	54	449	1.28	31.53	1.79	687	39	0.04	32.81	17.61
no.9	7.00	0.14	50	2.95	36	450	1.54	43.18	2.45	617	35	0.03	44.72	17.62
no.10	4.65	0.10	47	2.91	53	448	1.10	29.74	1.94	640	42	0.03	30.84	15.33
no.11	3.49	0.07	50	1.54	38	450	0.92	19.24	1.68	551	48	0.04	20.16	11.45
no.12	1.71	0.03	57	0.32	16	444	0.08	4.01	0.17	235	10	0.02	4.09	23.59

"Oil yield" was determined by Fischer-Assay method.
"Conversion ratio" = 0.85x(Oil yield/Organic carbon)x100
n.d.; not determined

values are typical nature of immature Type I kerogen, their kerogens can be regarded as Type I kerogen.

The high values of organic carbon content, oil yield and hydrogen index of the Dsunbayan oil shales indicate that those are "excellent" potential petroleum source rocks. Thus the maturity could be the only factor controlling the petroleum generation in their basins. The Dsunbayan oil shale is undoubtedly a petroleum source rock of the Dsunbayan oil field (1941–1969) in the East-Gobi basin (e.g., Petzet, 1990). Furthermore, Some oil seepages and bitumen deposits are found in the Choir-Nyalga, East Gobi and Choibalsan basins (Bat-Erdene and Enkhtugs, 1987). This means the petroleum generation of matured Dsunbayan oil shales in the deeper part of those basins. In the case of the Songliao basin, China, which is the nearest oil-producing basin having same origin as the Choir-Nyalga and Choibalsan basins, the relatively high heat flow (3.1–4.8℃/100 m) enables to generate heavy oil below 1300 meters depth and light oil below 1900 meters depth. If the heat flow in the Choir-Nyalga and Choibalsan basins is as same as that of the Songliao basin, petroleum must be generated below 1300 meters depth. The Mesozoic and Cenozoic Tectonic Map of Mongolia (A. L. Yanshin, 1979) shows the depression with more than 2000 meters thick sediments in the Choir-Nyalga basin. Thus the presence of oil and bitumen in those basins suggests the presence of matured Dsunbayan oil shales in deep horizon (probably below 1300 meters) in those basins, although there is no published data showing the presence of those oil shales in deep part of basins.

Acknowledgment: We thank Mr. C. Khurtz, former director of Institute of Geology and Mineral Resources, Mongolia (IGMR), for his contribution to this ITIT project. Special thanks are due to Messrs. T. Tseden, T. Battor, IGNR, E., Sato, MINDECO, Dr. Tumenbayar, Mongolian Academy of Science, Drs. S. Murao, S. Terashima and N. Mita, Geological Survey of Japan, for their helpful discussions and assistance for experiments.

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モンゴル下部白亜系 Dsunbayan 層オイルシェールの有機地球化学(予報)

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要　旨

モンゴルの下部白亜系 Dsunbayan 層から採取したオイルシェール試料計26点の有機炭素量，全硫黄量，シェール油生成量，ロックエヴァル分析値を報告する．

有機炭素量及びシェール油生成量はそれぞれ1.7–21.3%，0.32–11.82%の範囲にあり，地域また層準によって値に大きなばらつきを示す．総じて Eidemt 地域の試料は他２地域のものに比べてシェール油生成量が高く，その多くは，オイルシェールとしての可鉱敷居値である10 USgal/ton を上回る値を示す．

Dsnbayan オイルシェールは，その高い有機炭素量，油生成量，水素インデックス(Ⅰ型ケロジェン)から，Excellent potential source rock とみなされる．

(受付：1993年７月19日；受理：1993年９月22日)